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Antarctic Infrastructure Cooperation, Challenges and Opportunities

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This paper discusses the current state of international collaboration in Antarctica including the various mechanisms already in place to facilitate sharing, such as shared infrastructure, resources and logistics pooling. We discuss the barriers, catalysts and models of successful international collaboration through global analogues and a case study, aspects of which might be applied to the Antarctic in order to reduce the environmental impact of human activity in the region. Remote sensing opportunities are examined as a means to reduce environmental impact through an absence of physical presence on the continent, while highlighting a number of critical issues surrounding data access and sharing that should be addressed to encourage open sharing of data between nation states. We conclude with a number of high-level recommendations for policy makers pertaining to the implementation of the initiatives discussed.

ANTARCTIC INFRASTRUCTURE

COOPERATION, CHALLENGES AND OPPORTUNITIES

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STATEMENT OF PURPOSE:

HOW DO WE REDUCE ENVIRONMENTAL IMPACT AND INCREASE ACCESS TO ANTARCTICA THROUGH INTERNATIONAL COLLABORATION?

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GLOSSARY OF TERMS

- AAD – Australian Antarctic Division
- ADD – Antarctic Digital Database
- ANDRILL – Antarctic Geologic Drilling
- APN – Asia-Pacific Network
- ASMA – Antarctic Specially Managed Area
- ASOC – Antarctic and Southern Ocean Coalition
- ASPA – Antarctic Specially Protected Area
- ASPeCt – Antarctic Sea-Ice Processes and Climate Programme
- ATCP – Antarctic Treaty Consultative Party
- ATS – Antarctic Treaty System
- AUV – Autonomous Underwater Vehicle
- CAASM – Catalogue of Australian Antarctic and Sub-Antarctic Metadata
- CEE – Comprehensive Environmental Evaluation
- CAML – Census of Antarctic Marine Life
- CERN – European Council for Nuclear Research
- COMNAP – Council of Managers of National Antarctic Programs
- DROMLAN – Dronning Maud Land Air Network
- EPICA – European Program for Ice-Coring in Antarctica
- ESA – European Space Agency
- FINNARP – Finnish Antarctic Research Program
- IAATO – International Association of Antarctic Tour Operators
- ICGEB – International Centre for Genetic Engineering and Biotechnology
- IGY – International Geophysical Year
- IODP – Integrated Ocean Drilling Program
- IOOS & SOOS – Integrated and Southern Oceans Observing Systems
- NAP – National Antarctic Programs
- NASA – National Aeronautics and Space Administration
- NGO – Non-Governmental Organisation
- NSF – National Science Foundation
- NSDIC – National Snow and Ice Data Centre
- OECD – Organisation for Economic Cooperation and Development
- SCAR – Scientific Committee on Antarctic Research
- SESAME – Synchrotron Light for Experimental Science and Applications in the Middle East
- UNESCO – United Nations Educational, Scientific and Cultural Organisation
- UAV – Unmanned Aerial Vehicle
- USAP – United States Antarctic Program

ABSTRACT

This paper discusses the current state of international collaboration in Antarctica including the various mechanisms already in place to facilitate sharing, such as shared infrastructure, resources and logistics pooling. We discuss the barriers, catalysts and models of successful international collaboration through global analogues and a case study, aspects of which might be applied to the Antarctic in order to reduce the environmental impact of human activity in the region. Remote sensing opportunities are examined as a means to reduce environmental impact through an absence of physical presence on the continent, while highlighting a number of critical issues surrounding data access and sharing that should be addressed to encourage open sharing of data between nation states. We conclude with a number of high-level recommendations for policy makers pertaining to the implementation of the initiatives discussed.

INTRODUCTION

The Antarctic Treaty governs activity in Antarctica; it aims to promote international scientific collaboration and facilities sharing. Consultative Party status and the right to make decisions affecting Antarctica is obtained by conducting substantial scientific research, such as the establishment of a scientific station, and arguably this “boots on the ground” approach has limited the construction of shared facilities. In spite of this, much collaboration already occurs in the Antarctic in terms of international scientific partnerships and logistics support, with 28 out of 29 National Antarctic Programs reporting instances of collaboration (COMNAP, 2015). There are several existing precedents for minimising the environmental footprint of activity and infrastructure in Antarctica – from having no station, through annexes to an existing station or the succession of a station from one state to another.

The Antarctic Treaty recognises the benefits to science that can be achieved through international collaboration. The Environmental Protocol to the Antarctic Treaty promotes this collaboration through the sharing of facilities between national Antarctic programs in order to reduce environmental impact and the human footprint in Antarctica. A recent Council of Managers of National Antarctic Programs (COMNAP) survey has shown scientific collaboration is prevalent and increasing between international academic institutions and, to a large degree, in the logistical support to science on the ice (COMNAP, 2014). Despite this, 54 years after the Treaty entered into force, only one truly internationally shared Antarctic station exists today. This station is the Franco-Italian Concordia station.

In this report we investigate other existing models of successful international collaboration, from those with a similar mandate to the Antarctic Treaty (such as the European Space Agency), through to UNSECO-managed organisations to international business and philanthropic examples. We also discuss how the Antarctic Treaty System could learn from these examples to build on the current level of collaboration in order to increase scientific access to Antarctica. Alternative opportunities for the minimisation of infrastructure and footprint are considered, including expanding the use of remote sensing technologies, and recommendations are made throughout to increase the ease of access to data to facilitate data sharing and reduce duplication.

BACKGROUND AND OVERVIEW

Activity in Antarctica is governed by the Antarctic Treaty System (ATS) which acknowledges "*the substantial contributions to scientific knowledge resulting from international cooperation"* through "*freedom of scientific investigation"* and "*international harmony*" (Antarctic Treaty Secretariat, 1959/'61). Article III of the Treaty aims to encourage the establishment of cooperative working relations, and promote '*international cooperation in scientific investigation'* through the exchange of information and personnel '*to permit maximum economy and efficiency of operations*' (Antarctic Treaty Secretariat, 1959/'61).

This overarching spirit of international collaboration is reinforced under the Environmental Protocol to the Antarctic Treaty (Madrid Protocol) (1991) which calls for the:

'...promotion of cooperative programmes (Art. 6 (a)), consultation with other Parties with regard to the choice of sites for prospective stations so as to avoid cumulative impacts caused by their excessive concentration in any location (Art.6 (d)), the undertaking of joint expeditions and the sharing of use of stations and other facilities (Art. 6 (e)); with all activities planned and conducted so as to limit adverse effects on the Antarctic environment' (Art. 3.2 (a))(Antarctic Treaty Secretariat, 1991/'98).

Unfortunately these good intentions for scientific collaboration, facilities sharing and joint stations are often conflicted by original sovereign territorial claims and the reluctance to jeopardise or relinquish them (despite Article IV of the Treaty serving to freeze those claims). There is also a lack of any mode of enforcement in terms of environmental protection in the construction of new infrastructure, particularly if science is used as a justification. A country's Comprehensive Environmental Evaluation (CEE) is submitted for scrutiny, but with no means to deny construction of the proposed infrastructure, or enforce any suggestions made for its improvement (Hemmings & Kriwoken, 2010).

To obtain Consultative Party status and the right to participate in decision making under the Antarctic Treaty System, a State has to conduct *"substantial scientific research activity there, such as the establishment of a scientific station or the despatch of a scientific expedition"* (Art. IX.2) (Antarctic Treaty Secretariat, 1959/'61). Interestingly, there is no formal review mechanism under the Treaty to review whether a Party continues to meet this criterion (Dudeney & Walton, 2012). So although construction of a station in Antarctica is not a pre-condition for attaining Consultative Party status (Antarctic Treaty Secretariat, 2006), many Parties have taken this to be the case. This has led to a rapid increase in the number of stations and permanent infrastructure present on the continent (Figure 1) with concentrations in strategic locations relating to significant scientific objectives, ice-free land and feasible logistics resupply access (safe anchorages and runways), but also occupying geopolitically strategic locations investing in the potential access to any resources that may be discovered for future exploitation and economic benefit (Brady, 2015).

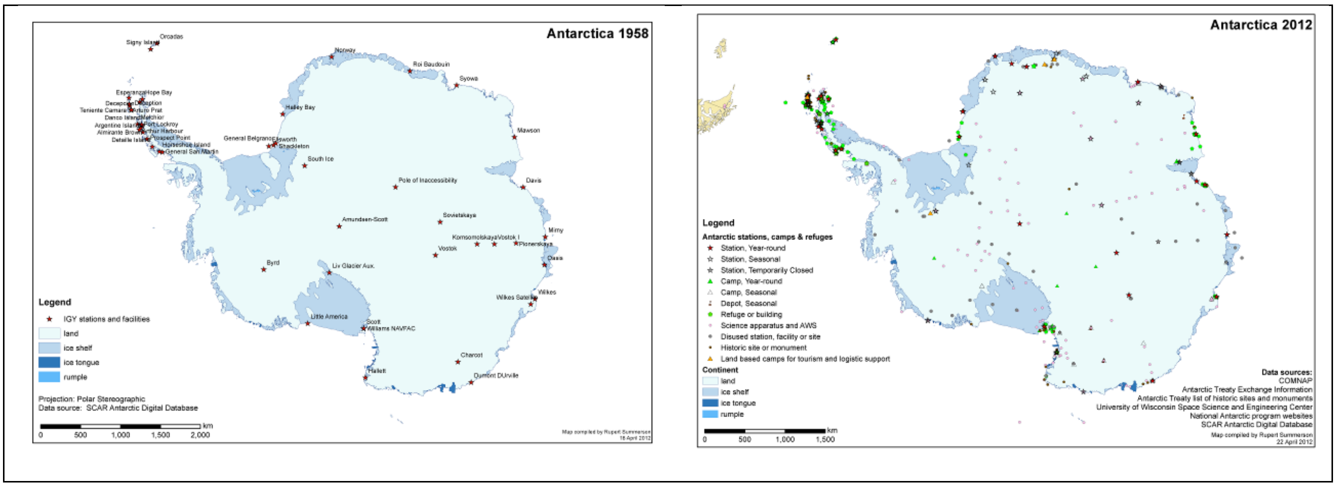

Figure 1 - Infrastructure of himan activity in 1958 and 2012, showing the continued increase in facilities since the IGY (New Zealand & Netherlands, 2012)

In 1990, the Netherlands became the first country to opt not to build a station upon achieving Consultative Party status. Instead for environmental concerns, scientists from the Netherlands collaborate with other NAPs, utilising spare capacity in other stations on a mutually agreed basis (Dudeney & Walton, 2012).

CURRENT OPERATIONS

There are currently 29 States (Consultative Parties) conducting [substantial] scientific research in the Antarctic from over 80 permanent facilities (Table 1).

Table 1 - The numbers of parties signatory to the Antarctic Treaty and of permanent infrastructure in Antarctica (COMNAP, 2015).

Number of Consultative Parties	29
Number of Contracting Parties	50
Number of seasonal stations/refuges	44
Number of year-round stations	40

To date, international collaboration has been driven by the recognition that many Antarctic science research questions are too large to be solved by any single nation. Although some of the National Antarctic Programs (NAPs) such as the United States possess the human resources, financial capital, and logistic capability to operate independently, collaboration occurs in cases where the challenges demand more intellect, manpower, money and infrastructure than any one person or nation can supply (Summerhayes, 2008).

Collaboration can benefit science in circumstances when:

- Logistic support from other nations is more practical and feasible in order to conduct research in a specific geographic location;

- Other nations have resources beyond those available to the leading NAP research scientists (e.g. sea icebreaking capability);
- Scientists from other NAPs are ahead in research, and collaboration can improve the quality of Antarctic science; or,
- The NAP has a skills shortage in a given area, and scientists from other programmes can make up for that shortage (National Research Council, 2011).

Collaboration means more science can be done more affordably and there are currently several examples of international collaboration in the Antarctic as shown in Table 2:

Table 2 - COMNAP survey data on international collaboration (COMNAP, 2014).

COLLABORATIVE INDICATOR	PERCENTAGE OF NAPs (proportion)
Involved in international scientific collaboration, partnerships or joint research	***97%*** (28/29) i.e. only 1 NAP did ***not*** collaborate with scientists from other programs.
Shared logistics	***97%*** (28/29)
Aircraft	89% (25/28)
Vessels	93% (26/28)
Land vehicles	46% (13/28)
Cargo operations	89% (25/28)
Fuel +/- waste management	86% (24/28)
Medical services	68% (19/28)
Training programs + SAR	50% (14/28)
Shared Antarctic stations or facilities	***93%*** (27/29)
Shared stations	90% (24/27)
Shared field camps	62% (17/27)
Shared airfields	52% (14/27)
Shared port facilities	37% (10/27)

CONTEMPORARY EXAMPLES OF INTERNATIONAL ANTARCTIC COLLABORATION

Examples of successful international collaboration in the Antarctic include:

INTERNATIONAL SCIENTIFIC COLLABORATION

- Off-ice collaboration – such as academic partnerships and collaborative science labs
- Data sharing (repositories)
- Shared use of research vessels
- Joint remote sensing platforms

Successful past collaborations include the International Geophysical and International Polar Years, and the Integrated Ocean Drilling Program (IODP) (Cooper, 2013).

More recent and current collaborative programs include:

- Joint drilling and analysis of the Vostok ice core by scientists from France, Russia, and the United States.
- EPICA (European Program for Ice Coring in Antarctica).
- ANDRILL (Antarctic Geologic Drilling) project - involving Germany, Italy, New Zealand, the United Kingdom, and the United States.
- Concordia astronomical observatory involving France and Italy.
- Gamburtsev solid Earth investigations involving the United Kingdom, the United States, Germany, Japan, Australia, and China.
- CAML (Census of Antarctic Marine Life).
- The Integrated and Southern Oceans Observing Systems (IOOS & SOOS) & ARGO Network (National Research Council, 2011).

JOINT LOGISTICS POOLS

The cost of, and budget for, logistics required to support science in Antarctica far exceeds that of conducting research itself. Considering 10 NAPs for which data was readily available, the proportion of their annual budget spent directly on science was between 12-31% with an average of 24% (Figures 2, 3).

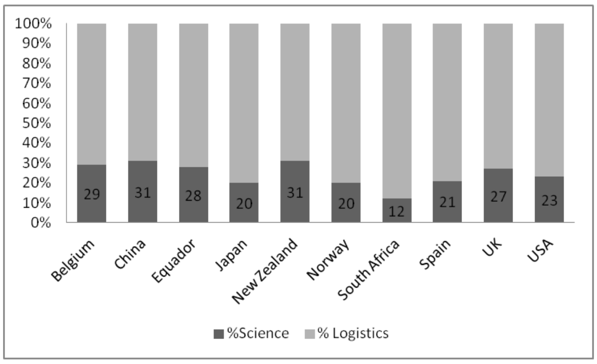

Figure 2 - The proportion of NAP budget spent on logistics and science ([COMNAP, 2015](#)).

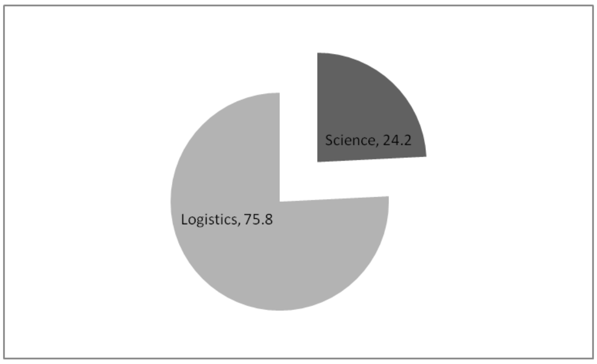

Figure 3 – Average distribution of science and logistics spend across NAPs ([COMNAP, 2015](#))

With such a large proportion of the budget allocated to supporting rather than conducting science, and with science being the basis of presence in the Antarctic, it makes sense to try and reduce costs by the sharing of logistics resources. For example:

- New Zealand & USA, Korea, Italy, +/- China - aircraft, ships, ports, land facilities.
- DROMLAN – the Dronning Maud Land Air Network consisting of Belgium, Finland, Germany, India, Japan, the Netherlands, Norway, Russia, South Africa, Sweden and the United Kingdom.
- Australia & France - ships, port facilities.
- King George Island – 11 permanent bases of Argentina, Brazil, Chile, China, Ecuador, South Korea, Peru, Poland, Russia, Uruguay, and The United States, all accessed via a Chilean runway.
- Icebreakers - USA used the Swedish icebreaker *Oden.*
- Shared ports – 5 Antarctic Gateway cities – Christchurch, Hobart, Ushuaia, and Punta Arenas & Cape Town.
- Shared traversal capacity.
- Joint procurement.
- Shared power/fuel – New Zealand owned Wind farm, run by the USA.

ALTERNATIVE COLLABORATION STRATEGIES

For reasons of practicality for operating in the Antarctic, there are several alternatives for cooperation between NAPs that do not require the construction of new stations. These arrangements minimise or avoid entirely the footprint associated with establishing a new facility, as well as reducing operational costs.

Alternatives for which there is already a precedent include:

No station

- The Netherlands operates without a station of its own, instead making significant contributions to the operations of partner NAPs (Dodds, 2010). Belgium and Ecuador previously operated in a similar fashion (Dastidar & Persson, 2005).

Annexes

- Some States have arrangements to set up annexes to an existing station. Germany has two such annexes: Dallman Laboratory at Argentina's Jubany station, and a Geodetic Observatory at Chile's O'Higgins station.

Base transition / succession (the transfer of bases from one State to another)

Between Claimant countries:

- E.g. USA to Australia – Wilkes was run as a joint US/Australian station from early 1959, before being leased to Australia as a sole operator in 1961. Australia operated Wilkes until 1969 prior to rebuilding Casey Station on the same site

Claimant countries to new ATCPs, thereby saving them having to build their own new infrastructure:

- E.g. Australia to Romania - a 10 year Memorandum of Understanding for Romania to use Australia's 'Law Base' as 'Law Racovita' was signed in 2005, (Hemmings, 2011).

- The United Kingdom has also transferred stations: Adelaide Island to Chile in 1984, subsequently operating as Teniente Carvajal. In 1986 it transferred View Point to Chile, which it has since operated as Canas Montalva; and in February 1996 it transferred 'Faraday' to Ukraine, which now operates as Vernadsky. The Brazilian station Comandante Ferraz opened in 1984 on the site of the former British station Admiralty Bay.

Shared stations

- Prior to the signing of the Antarctic Treaty, Maudheim operated during the 1949–'52 Norwegian–British–Swedish Antarctic Expedition.

- Hallett Station - a joint United States/New Zealand station was built by the US, operated jointly as a year-round station from 1956/'57–1964, then as a summer-only facility until its abandonment in 1973.

- The jointly managed Franco-Italian station of Concordia is the most unique collaborative Antarctic venture to date (Dastidar & Persson); it is not located within the French claimed sector, but in the Australian Antarctic Territory, roughly equidistant from the French base of Dumont d'Urville and the Italian base of Mario Zucchelli, a location ideal for making accurate astronomical observations (Hemmings, 2011).

WHAT LIMITS SHARING?

Barriers to international collaboration include:

- Variations in the organisational and funding structure between national Antarctic programs;

- reduction in funding within a national Antarctic program limiting its ability to host or participate in international collaborations;
- Disparity between individual national policies or objectives;
- Absence of country-to-country Memorandums of Understanding;
- Spatial limitations - regional cooperation is more easily manageable than continent-wide or global partnerships;
- Language differences; and
- Lack of capital investment on Antarctic-related infrastructure.

(COMNAP, 2014)

As a result of these barriers, there are several examples in the Antarctic of apparent duplication, facilities from different NAPs in extremely close geographical proximity, often working on similar scientific projects, sharing logistics, though neglecting the principles of the Protocol and Antarctic Treaty by not sharing facilities.

Contemporary examples are:

- McMurdo Station (US) and Scott Base (NZ) – 3km apart.
- Aboa and Wasa stations (Finland and Sweden) – located on the same Nunatak, 200m apart (FINNARP, 2015).
- King George Island – 11 bases of 11 different NAPs within 35km of each other.

As a whole, the pattern of station location does not obviously correlate with significant scientific research opportunities (Hemmings, 2011). The early geopolitical drivers of national interests in Antarctica, for territorial claims and mineral prospecting, would seem either to no longer apply, or at least not to carry the same importance as they once did, at least as long as the status quo of Article IV and the Madrid Protocol remain.

The excessive concentration of stations in some locations, coupled with a subsequent decline of research opportunities in those areas, may be a factor driving Parties to new locations. However, the premise that an actual physical presence in Antarctica remains the main currency of influence within the Antarctic Treaty System (ASOC, 2004b) fuels the desire of some States to assert their national identity, promoting their geopolitical interests in the region, perhaps with undertones of perceived future commercial interests.

If the sentiments of the Antarctic Treaty and its Environmental Protocol are adhered to more strongly, at the expense of foregoing perceived potential territorial or commercial gains, then the human footprint of development in Antarctica would surely be more constrained and international cooperation truly more collaborative. In the future, before building or upgrading any facilities in the Antarctic all alternatives should be carefully considered, especially in otherwise pristine regions. With these ideas in mind, environmentally responsible scientific practice compatible with the designation, objectives and principles of the Antarctic Treaty and its Environmental Protocol should be employed (ASOC, 2004a).

ALTERNATIVES TO PHYSICAL PRESENCE – REMOTE SENSING

Before a reduction on the human footprint in Antarctica can be discussed, nation states must agree on what constitutes the environmental baseline from which human impact is compared (Broady, 1988; Keys, 1988). Arguably, no presence in Antarctica is without human-induced environmental impact (Maslanik & Barry, 1990), though remotely-facilitated approaches may help to reduce and monitor the effects while still conducting effective science.

Remote sensing at the poles is regarded as being fraught with difficulties not experienced at lower latitudes. Situational conditions such as the polar night, cloud cover, extreme temperatures, and the curvature of the Earth are just some of the limiting factors in the Arctic and Antarctic that contemporary remote sensing techniques are yet to fully overcome. Add to this historical precedence of data silos at a national, or even project level (Maslanik & Barry, 1990), and remote sensing becomes only part of the solution, with coherent governance, policy, and data sharing of commensurate importance.

The recently established Scientific Committee on Antarctic Research (SCAR) Remote Sensing Action Group provides early indications of a coherent strategy towards remote sensing in the Antarctic, though the group's mandate is narrowly focused on Antarctic biota (SCAR, 2014) rather than to the wider Antarctic environment. This appears short-sighted, as assessing the human impacts of Antarctic activities has also come to the forefront in recent Horizon Scan discussions (SCAR, 2013), along with a host of other questions that will invariably include, and benefit from advances in remote sensing in the Antarctic.

OBSERVATIONS OF OPPORTUNITY

For some disciplines, frameworks of Antarctic remote sensing have existed for a number of years. A notable example is the observation of sea ice through the Antarctic Sea-Ice Processes and Climate Programme (ASPeCt). At a protocol level, ASPeCt as it currently stands only "encourages" ships entering the pack ice to make observations (AAD, 2011). Such observations are not mandatory nor are they necessarily made in areas of key scientific importance, but rather by vessels already en-route to other areas of the continent (SCAR, 1996). While the benefits of comprehensive data coverage are outweighed by the environmental and financial cost of collection at scale for the foreseeable future, a mandate for the collection of data (perhaps automatically) by vessels entering the pack ice for *any* reason is an opportunity to improve data coverage overall, and as described by Toyota (2009), is relatively straightforward to facilitate with commodity hardware.

This leads to a notion of "observations of opportunity", whereby observations could be made during the course of other activities in the Antarctic, such as the use of aerial photography for aircraft flying inter- and intra-continentally, as well as multi-sensory payloads for orbital platforms with application in a diverse range of disciplines.

PROXIMITY AND PROXIES

It is important to note that not all phenomena can be observed remotely, with much research requiring physical proximity to the subject. Further to this, in many cases it is necessary or desirable to combine remotely observed and field measurements (Chunxiaa et al., 2008), such as with ground-truth validation of sea ice thickness observation, until models develop to a point that they can rely on remotely sensed data alone.

In the case that the subject of study cannot be observed remotely, remote sensing techniques do offer the capability to observe proxies to the phenomenon from which researchers can infer results. For example, blue ice zones have been used in the detection of meteorite concentration where direct observation was not possible (Graham & Annexstad, 1989; Lucchitta et al., 1987). However, this assumes that the phenomenon or proxy of interest can be suitably captured at the desired spatial and temporal resolution from remote mechanisms.

The use of unmanned/autonomous vehicles (UAV, AUV, etc.) has been shown to produce *hyperspatial* and *hypertemporal* (extremely fine-grained) resolution data for studies where satellite observations were otherwise unsuitable (Lucieer et al., 2011). The use of UAVs is typically considered where a study site is limited, restricted (e.g. ASMAs/ASPAs), inaccessible, or too costly to reach. UAVs are not a new phenomenon in Antarctica; they have been used in research since the mid 2000s (e.g. Funaki & Hirasawa, 2008; Maslanik, 2002) and some NAPs (such as the British Antarctic Survey) already have significant investment in the technology (British Antarctic Survey, 2015).

Several ATCP members have expressed concern over the use of UAVs in the Antarctic region, noting safety, environmental and operational risks with the technology (Antarctic Treaty Secretariat, 2014); however, despite the scientific benefits of UAVs, their use in Antarctic is still unregulated. Formal discussions are scheduled to take place at the next consultative meeting following a working paper on permissible UAV use presented in 2014 by Germany and Poland (Antarctic Treaty Consultative Parties, 2014). This paper was largely a call to action with general talking points over strategic direction and the International Association of Antarctic Tour Operators (IAATO) has been requested to present draft UAV guidelines in a consultative capacity based on experiences with passengers seeking to fly drones.

The intention is to start a constructive discourse on the permissible use of UAVs rather than their prohibition in the region (IAATO, 2014), however, some nation states have already begun implementing their own national program guidelines contrary to that intention, requiring authority from national bodies (e.g. USAP/NSF) before use (NSF, 2014). It is recommended that discussions proceed at the ATCP level to ensure a consistent framework for the permissible use of UAVs going forward in the Antarctic region.

REMOTE SENSING FOR PLANNING

Maslanik and Barry (1990) argue that remote sensing could be used to identify the least-sensitive sites for construction, as well identifying shipping hazards for vessels in the Antarctic. Safe, fuel-efficient corridors could be identified through contemporary observation techniques (e.g. altimetry, upward-looking sonar, bathymetry etc.), reducing the risk, financial cost and limiting environmental impact. Remote sensing can be used to assess this environmental impact, assigning responsibility and to aid in environmental disaster mitigation strategies (e.g. ice draft can be used to assess containment potential of ocean contaminants)(Maslanik & Barry, 1990; Melling et al., 1995; Wadhams, 2012).

In other forums, multispectral analysis is often used to quantify urban growth and can be facilitated through the use of satellite imagery, which is (or could be made) readily available for base sites using high spatial/temporal resolution satellite programmes such as Landsat-8 (up to ±81.6°) (NASA et al., 2000) and potentially polar-orbiting satellites closer to the pole. Further to this, image differencing and computer vision techniques (Lillesand et al., 2004) can be employed to observe base expansion over time from space without the need for ground-based measurements nor human evaluation. Given the relative sparseness of infrastructure in Antarctica, that which is visible from space (e.g. bases and stations) has the potential to be monitored even with contemporary technology.

DATA

Article III (1c) of the Antarctic Treaty stipulates that scientific results and observations are to be exchanged and made freely available to other national programs (Antarctic Treaty Secretariat, 1959/'61), as well as to the general populous. This is perhaps in contrast to the apparent political economy of data in a place where scientific output is currency (Dean et al., 2008), and where effective occupation has historically been facilitated by the collection of scientific observations or physical surveying (Dodds, 2000). Historical examples such as the Ronne saga between America and U.K., (in which data sharing and ownership caused geopolitical tensions) (Dean et al., 2008), have taught us that there is a fine line between transparent data sharing and ownership, especially when geopolitical interests or academic competition come into the fore, and despite good intentions there is still a marked absence of true international accord on the sharing of Antarctic data between nation states (Nelson, 2009).

DATA ACCESS

One might argue that the problem lies not in collection, but in access to data, and that a central repository might bridge the silos between nation states. However, the concept of central data repositories has been broached before, with the establishment of World Data Centres out of the International Geophysical Year (IGY). This notion that was later conceded by the National Science Foundation as being assumedly better managed at a state and institution level (Dean et al., 2008), and is particularly the case given the ever-increasing volume of Antarctic data as observation technology advances (Cooper, 2013). Consequently, much of the Antarctic data lies within national repositories (e.g. Catalogue of Australian Antarctic and Subantarctic Metadata (CAASM), National Snow and Ice Data Centre (NSIDC) etc.), academic institutions and on the desktop computers of researchers.

While these repositories are useful assuming one knows where to look, others clearly contravene Article III (1c), with data either not publicly accessible or otherwise exceedingly difficult to locate. Metadata catalogues such as the Antarctic Master Directory (NASA), Antarctic Digital Database (ADD) and general academic search engines have made modest forays into the overall indexing of available data, however there is still significant scope to develop a meta-catalogue of Antarctic data. A dedicated Antarctic Metadata Index crossing all scientific disciplines would streamline access to Antarctic research by directing to the appropriate national/academic repositories when queried, though not necessarily holding data of its own.

Adding to the complexities of remote sensing alternatives in the Antarctic is the debate on data formats, standards and to what level of processing proprietary formats constitutes "open access". Cloud (2002) discusses the national sensitivities present when dealing with classified technologies, which may account for the current state of different data formats, however, reduction of data into standard, open formats is highly recommended to bridge these differences and increase the utility of data collected in the region.

Final considerations for access to data collected in the Antarctic are the timelines under which data is released. Several studies have been conducted on the appropriate mechanisms for releasing scientific data while still maintaining privileged access for researchers. One such model from (Cooper, 2013) proposes three options:

1. **Data library**
   Privileged access to researchers for N years, restricted access to collaborators for M years.
   Open access after N + M years.

2. **Access timelines (e.g. NSF, 1998)**
   Data sent to data centres within X years, allowing researchers privileged access to publish.

Open access after this time.

3. **Open access (e.g. Suber, 2010)**
   Data is made immediately available to the public to encourage collaboration.

Regardless of the model chosen, policymakers should be wary of maintaining the currency of any data collected in the Antarctic through timely access. With support from academia, an option to minimise the time from collection to open access is highly recommended to reduce the potential for duplicate collection between access periods.

OTHER CONSIDERATIONS

Consideration should be given to the actual collection of observations, such as the polluting effects of aircraft used in aerial observations or the construction of terrestrial reception stations (Czúni et al., 2012) still required for space-borne observations (due to the curvature of the Earth), as well as the support infrastructure required for ongoing application. Likewise, consideration should be given to telecommunications infrastructure in the Antarctic, which is still limited by way of operational bandwidth to the rest of the world and often shares satellite relays with other programmes (such as the ISS or Hubble Space Telescope) (USAP, 2015) rather than operating under dedicated equipment. As a result, the transport of observational and scientific data is slow, unpredictable, and often at high financial cost off the continent despite leveraging non-Antarctic collaboration and resource sharing in the process. This has prompted national interests to invest in dedicated Antarctic telecommunications infrastructure (e.g. Antarctic Broadband, 2011), leveraging international expertise through collaborative partnerships.

OVERCOMING BARRIERS TO COLLABORATION

Reducing the physical footprint and environmental impact of the National Antarctic Programmes will require the establishment of management and regulatory frameworks that enable the members of the Antarctic Treaty System to collectively plan and manage the global Antarctic science programme and how it is supported. This will need to include activities both on and off the continent. For this to occur, the barriers to cooperation between current Treaty nations, and to new countries wishing to join the Antarctic Treaty System and/or participate in Antarctic science will need to be overcome through one or more catalysts for change. For example, a co-ordinated approach needed to answer the questions identified in the 2014 SCAR Horizon Scan (Kennicutt et al., 2015) may be one such catalyst.

Similar barriers to international collaboration have existed or continue to exist across a wide spectrum of different scientific disciplines (OECD, 2012). Despite this, global science collaboration is increasing and in recent years new scientific powers like China, India and Brazil have emerged. Nations in the Middle East, South-East Asia and North Africa are also making an increasing contribution to science globally (Wilsdon, 2011). Over 33% of all articles published in international journals are internationally collaborative, up from a 25% 15 years ago. Wilsdon (2011) describes three main factors that are likely to have driven this increase in collaboration:

- The search for quality, researchers searching out the best collaborators and facilities regardless of location;
- The search for economies of scale and increased efficiency and effectiveness in projects that need significant infrastructure, equipment or large numbers of scientists and;
- The need to combine data when studying problems of a global nature.

The Large Hadron Collider built by the European Council for Nuclear Research (CERN), and the Human Genome project are examples of collaborations that are driven by the economies of scale involved; where no one nation possesses the financial, intellectual or logistical capability to undertake the task individually. Understanding the impact of climate change or the spread of pandemics are more recent examples of global problems that have, and continue to necessitate international collaboration (Wilsdon, 2011). Other examples of successful international collaborations that have developed as a result of one or more of these different pressures/catalysts include:

- The European Space Agency (ESA);
- The European Southern Observatory (ESO); and
- The International Centre for Genetic Engineering and Biotechnology (ICGEB)

A fourth catalyst of international collaboration has been the desire to expand the number of countries conducting scientific research and development, with particular emphasis on aiding the sustainable development of developing nations through "investing in science, transforming the policy environment and making necessary institutional adjustments" (SESAME, 2010). Examples of collaborations of this type include the Synchrotron Light for Experimental Science and Applications in the Middle East (SESAME) (SESAME, 2010) and the Asia-Pacific Network for Global Change Research (APN).

MODELS OF INTERNATIONAL SCIENCE COLLABORATION

Many different models of international science collaboration exist. They vary in the scope of their work, the geographical spread of their members, the nature of their members, their funding and spending mechanisms, and their governance and management arrangements (OECD, 2012). Bodies range from those funded entirely by governments, to those funded by public companies, by NGOs, by philanthropists like the Bill and Melinda Gates Foundation, and by charities such as the Welcome Trust. Many are funded by a mix of those types of organisation (Wilsdon, 2011).

The variety of different aims of these collaborations means that an ideal governance model for them does not exist (OECD, 2012), as each organisation has developed to suit its own needs. Many organisations have already developed frameworks to collectively manage infrastructure and their environmental impact. Examining these models more closely has the potential to identify options suitable for use by the Antarctic Treaty System, as they help us understand how changes to the current system could be implemented and what the direct and indirect benefits of those changes could be.

CASE STUDY – THE EUROPEAN SPACE AGENCY

An organisation with an established framework for collectively managing its science programmes and it supporting resources including infrastructure is the European Space Agency (ESA). Founded in 1964 to coordinate and support Europe's space activities, ESA was established to develop a space programme for exclusively peaceful purposes. The organisation does this by making better use of existing resources devoted for space as no European nation had the human, technical nor financial resources required to do so alone (ESA, 2014a).

ESA operates in accordance with the ESA Convention, an international treaty comparable to the Antarctic Treaty, and governed by council comprising representatives of its 20 Member States, plus Canada (a long-term partner with the same rights)(Figure 4). ESA is an independent legal entity with an annual budget of €4B, derived from business, the European Union and its members. The contributions of each Member State are based on a scale adopted by a two-thirds majority of all Member States. They are based on average national income (GDP), up to a maximum of 25% of the total collective amount (ESA, 1973). ESA has cooperation agreements with 8 other states, a long-term Cooperation Agreement with Canada and it works with a range of other agencies, organisations and institutions on international programs (apart from ESA itself), such as the International Space Station (ISS). This is in contrast to the Antarctic Treaty System and demonstrates that scientific cooperation is indeed possible at an international scale.

Figure 4 - ESA Member and Cooperative States (ESA, 2014b)

Supported by a number of committees, the ESA Council (Figure 5) is responsible for approving all activities and programs, and for determining the resources that will be made available to it every 5 years. These decisions require the unanimous vote of all members for major decisions (majority vote in other cases). ESA operates a number of different programmes and activities, both mandatory (for all members) and optional.

Activities are determined by considering 3 main objectives:

- Pushing the frontiers of knowledge
- Supporting an innovative and competitive Europe; and
- Enabling space-based services

(ESA, 2014b)

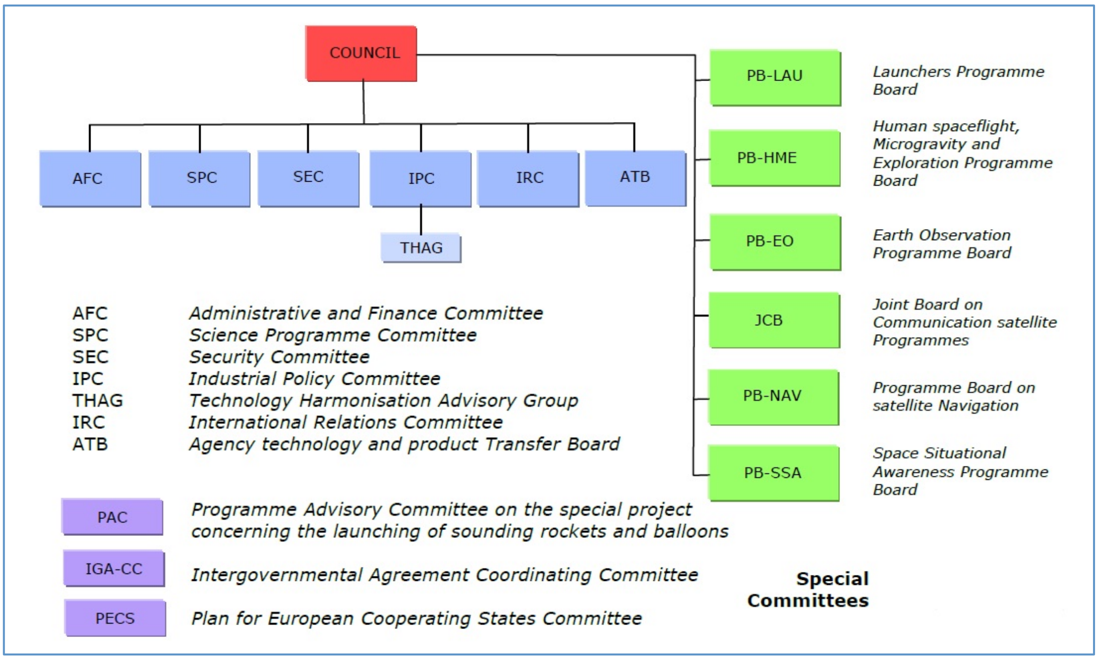

Figure 5 - ESA organisational structure (Czech Space Portal, 2013)

ESA operates a number of facilities across Europe and the rest of the world (Figure 6), managed in accordance with the agency's infrastructure management plan. ESA controls which facilities are needed, how and where they are built, and how they are maintained. Member States are required to provide existing facilities to the agency and new facilities are only built when no alternatives are available. Member States can use facilities of ESA for their own programs if sufficient capacity is available.

ESA seeks to ensure equal return on investment to each country through the principles of geographic return. That is, around 85% of funding flows back to European industry and supports around 35,000 jobs, demonstrating the commercial benefits of the collaboration. Furthermore, the commercialisation of ESA programmes (e.g. Eumetsat, Arianespace, Eutelsat, Inmarsat) demonstrates that the collaboration is an effective catalyst for business and contributes to the betterment of citizens.

In accordance with the ESA Convention, all scientific and technical information from its programmes is owned by ESA. ESA ensures publication and sharing of this data and makes it freely available to all member states and institutions. To support wider economic and developmental goals ESA ensures relevant data and information is shared with other sectors such as agriculture and logistics.

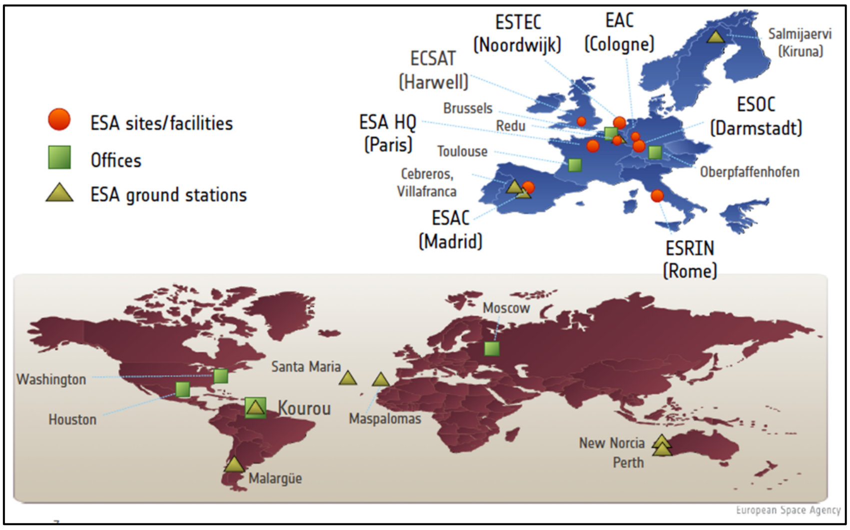

Figure 6 - Locations of ESA facilities (ESA, 2014b)

Of ESA's members, only 2 (Ireland and Luxembourg) are not part of the Antarctic Treaty System. This illustrates that where sufficient need is identified, a large number of Antarctic Treaty nations have already been prepared to establish the type of centralised funding, decision-making and resource management mechanisms necessary to reduce the physical footprint and environmental impact of the Treaty Nations.

CONCLUSION

Working with organisations like ESA and others with expertise in data sharing and environmental regulation would enable Antarctic Treaty nations to better understand the management and regulatory frameworks they use. This will enable them to identify suitable measures for implementation in the Antarctic Treaty System. For example, the Group on Earth Observations (GEO) (which counts all but 11 of the ATS nations as members) is an organisation focusing on the more effective sharing of data (GEO, 2014). Similarly, the International Maritime Organisation (IMO) are currently developing and trialling environmental regulations and the Division of Environmental Law within the UN Environmental Programme is examining how global commons can be better regulated, with a specific interest in Antarctica (UNEP, 2015).

Achieving cooperation on a global scale involves higher transaction costs than maintaining the status quo of where individual countries plan and manage their scientific activity and support (OECD, 2012). Like the establishment of the ATS, the establishment of new management and regulatory frameworks will be both challenging and initially costly. While it may be possible to establish an entirely new organisation to manage and regulate support to Antarctic science, it is unlikely that all the ATS countries would accept a shift to entirely new arrangements. Consequently, adapting the current system is likely to be a more realistic means to increasing cooperation.

Where possible, parties should investigate options that lie within remote sensing, taking advantage of opportunities for collaborative observation and the advancement of remote sensing technology in Antarctica. Opportunities to monitor human activity and environmental impact should be explored alongside scientific research through remote sensing, leveraging the tools and techniques of other fields, such as urban sprawl pattern detection. In terms of data access, silos should be bridged through stringent data sharing and access models to reduce physical presence on the continent, further reducing the environmental impact of human activities.

Confidence building will be essential to the implementation of the initiatives discussed and a long-term strategy is paramount. The need for a coordinated programme of science required to address the questions in the Southern Ocean and Antarctic science Horizon Scan is the most likely catalyst for the changes discussed. As such, it is logical that SCAR should initiate and lead this work. To ensure all stakeholders within Antarctic science and science support are included, the involvement of IAATO, COMNAP, CEP, CCAMLR and others is also critical, and the establishment of a governance board comprising senior members of these organisations should be established. A programme of work should be developed and a working group established to implement the programme. If necessary, SCAR, COMNAP and CEP should be bolstered to enable this work to commence.

The work should begin by investigating the work of OECD, the Royal Society and UNESCO, and suggestions include initiating secondments to other organisations like ESA, GEO and the IMO; and consulting with external advisors and diplomats who have worked in, and with, those organisations.

To take advantage of potential opportunities for collaboration before these frameworks are put in place, the Treaty System should seek to build upon and existing collaborations and relationships. Significant collaboration exists between countries who operate in the same parts of Antarctica and use the same gateway cities, notably East Antarctica, Ross Sea Region and the Antarctic Peninsula (COMNAP, 2014). This often comes in the form of bilateral agreements and Memorandums of Understanding. Expanding the agreements to be regional in scope could deliver more effective collaboration and greater economies of scale, further efficiencies, and also provide a means to develop and test management and regulatory frameworks before they are established across the whole Treaty System. These could include developing shared funding pools for research, for equipment procurement and infrastructure management and long term development. More immediately, the planned development of McMurdo Station (Hill, 2013) may represent an opportunity for New Zealand and other nations operating in the Ross Sea region to reduce their footprints by sharing infrastructure.

RECOMMENDATIONS

- The Antarctic Treaty System should investigate the frameworks for environmental regulation being developed by the International Maritime Organisation (IMO).
- A board led by SCAR and comprising members of IAATO, COMNAP, CEP and CCAMLAR should be established to lead the development of management and regulatory frameworks necessary to improve collaboration among Treaty nations.
- A working Group comprising members of SCAR, COMNAP and CEP should be established to conduct the work necessary to develop and implement appropriate frameworks.
- Broaden the mandate of the SCAR Remote Sensing Action Group to include more general applications of remote sensing.
- Where possible, increase the use of remote sensing to observe natural phenomena or their proxies without physical proximity and mandate the opportunistic, automated collection of observations in the Antarctic by vessels entering the pack ice, as well as inbound/outbound flights.
- Encourage international collaboration on the design of satellite platforms to further generalise their use through multi-sensory payloads.
- Continue multilateral discussions at the ATCP level to establish a legal framework for the use of UAVs for scientific research in Antarctica and establish stringent guidelines for the use of drones recreationally by tourists in Antarctica
- Greater international collaboration through simplified, coherent open access to Antarctic data; facilitated through the establishment of an Antarctic Metadata Index, stringent access models, and the standardisation of data away from proprietary formats to increase the accessibility and utility of data between nation states. This should begin with an investigation the data sharing protocols and mechanisms being developed by the Group on Earth Observation (GEO).

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